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THESIS

AN EXPERIMENTAL INVESTIGATION
OF THE EFFECTS OF SOFTWARE SIZE INCREASE
ON SOFTWARE PROJECT MANAGEMENT BEHAVIOR

by

Diana L. Baker

March , 1992

Thesis Advisor: Tarek K. Abdel-Hamid

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Increasing demand for software and increasing shortfalls of programmers have focused efforts to improve software project productivity on the role of the software project manager. The complex dynamics of software project development, and the 'visibility' of the project, affect decision making and performance to a large degree. Using the System Dynamics Model for software project management, these and other issues can be evaluated with low financial risk or outlays through simulation of software projects.

This thesis investigates the effect of changing one of the dynamics (i.e., size) on the behavior and performance of the project manager by using a simulation of an actual software project in a game environment. Analysis of the results indicates that increased visibility significantly improves project schedule.

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ABSTRACT

Increasing demand for software and increasing shortfalls of programmers have focused efforts to improve software project productivity on the role of the software project manager. The complex dynamics of software project development, and the "visibility" of the project, affect decision making and performance to a large degree. Using the System Dynamics Model for software project management, these and other issues can be evaluated with low financial risk or outlays through simulation of software projects.

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TABLE OF CONTENTS

I. INTRODUCTION

A. BACKGROUND

Software project management is not only facing a serious backlog of projects that need to be maintained, created and designed, but also an increasing shortfall of trained programmers available to do the job. Recognizing the increased workload and the decreasing workforce, technological advances have assisted productivity, but show no signs of catching up with, let alone meeting demand.

As usual, management of the process has come under increasing scrutiny as the last hope of the software project manager. Software project management is far more complex, however, than the management of a hardware or industrial project. The dynamics of resource management are far more complex, due to the continual shifts in work force, technological situation, supply and demand of supporting resources, requirements and/or specifications, etc.

Two crucial elements of any project manager's resource allocation plan are people and time/cost. Faced with the realities of a competitive job market, tight schedules and a budget, the manager must consider not only those factors, but their possible effects on all other factors. Of significant interest, given the statistics on personnel availability and

project size growth, are projections of what is best for a manager to do in the face of schedule expectations and growth realities.

DeMarco asserts that the "political" pressures affecting schedule and cost status reporting are more appropriately called sociological factors, because of the complex social dynamics involved [Ref. 1]. Because of this, the status reported and its interpretation often negatively affect the progress of the project. The concept of project "visibility," an accurate representation not only of the project's size but also of actual progress made, is cited in the literature (DeMarco, Abdel-Hamid) as being key to controlling and reducing project schedule and cost overruns [Ref. 2] [Ref. 3].

The "90% Syndrome" is a tendency in which Baber suggests

> Estimates of the fraction of work completed [increase] as originally planned until a level of 80-90% is reached. The programmer's individual estimates then increase only very slowly until the task is actually completed [Ref. 4].

According to Abdel-Hamid [Ref. 2], there is "ample evidence in the literature to indicate that this phenomenon is pervasive in software project management," and that it affects many of the other factors involved. How the project manager copes with this problem while managing resources to deal with changes in project size or complexity is of crucial importance to the success (being on time, within budget and meeting the user requirements) of a project.

B. PURPOSE OF RESEARCH

The purpose of this thesis is to design, construct and execute an experiment involving the single project management environment, using the Systems Dynamic Model (SDM) gaming interface. The Systems Dynamic Model is a comprehensive model of the dynamics of software development, allowing simulation, testing and evaluation of different software project management environments. It allows one or several factors to be manipulated while holding all others constant, and offers a cost effective opportunity to study the dynamics of decision making in a dynamic environment.

This experiment addresses the effect of project size change on project processes and performance. The concept of visibility has been discussed in terms of management situations, but has not been empirically tested in any project management domain in the literature dealing with change or project management.

The gaming interface presents the subject managers with a standard interface to the model; they are required to make staffing level decisions and project cost estimates through the design and testing phases of a software develoment project. Their performance is measured by their final cost and completion date of the project. The SAS statistical software is then used to measure process and performance deviation significance; the effect of the manipulated

variables on the actions and performance of the subject managers.

C. SCOPE OF RESEARCH

The scope of this research includes the design, construction, preparation of software and documentation, and execution of the single project experiment to investigate the following hypotheses (stated in alternative form):

1. Process Hypotheses

1a. Project managers presented with gradual change in project size will make different cost estimate decisions than project managers presented with an abrupt increase in size of the same magnitude.

1b. Project managers presented with gradual change in project size will make different staffing decisions than project managers presented with an abrupt increase in size of the same magnitude.

2. Performance Hypothesis

Project managers presented with gradual change in project size will perform differently than project managers presented with an abrupt increase in size of the same magnitude.

D. ASSUMPTIONS

The students in this experiment were fifth-quarter (in a six-quarter curriculum) graduate students enrolled in the

Computer Systems Management curriculum at the Naval Postgraduate School. Although the students were not actual software project managers, the amount of education in software project management and related subjects provided thus far in the curriculum, coupled with general management experience in their careers to date lends credence to the assumption that the results of the experiment and the findings and conclusions would be representative of the industry. This assumption is further supported by the findings of William Remus [Ref. 5].

E. THESIS ORGANIZATION

Chapter II is a description of the experiment design, to include software and documentation and preparation of the experiment itself and the description of a trial experiment, its lessons and the changes made to the experiment as a result. Chapter III describes in depth the methodology, sample population and conduct of the experiment. Chapter IV provides a validation and analysis of the experimental raw data. Chapter V summarizes the findings of the previous chapters and their implications, and provides recommendations for further research.

II. PREPARING THE GAMING INTERFACE

A. EXPERIMENTAL DESIGN

This experiment uses the Systems Dynamic Model to develop an experimental simulation of a software project; this allows the creation of a "game" not unlike a flight simulator, in that the player must pilot the project from point A to point B within given constraints and guidelines. The simulation mimics a software project from the start of its Design Phase until the end of the Testing Phase.

The player, or subject, plays the role of manager of a software project; when he/she initiates the 'game" program, the program presents an introductory screen (Figure 2-1) that reiterates the decisions (staffing levels and project cost estimates) that the player is expected to make as manager based on periodic status reports. It then prompts the user to initiate the first simulated time interval of 40 days (two months) and performs the simulation.

Once the simulation of an interval is completed, the game program displays a revised status report of the project based on the 40-day interval, to include an updated size estimate and an estimate of the percentage of development and/or testing which has been completed (Figure 2-2). Based on this information, the user may input a new desired staffing level,

Important Points to Remember !!!!!!!!!
****

- You are not allowed to discuss this exercise with anyone other than a lab attendant. Please refrain from discussing this with other class members until they have completed the project.

- The system will run through the first simulation period (2 months) and provide you with a status report. At the end of each reporting period, you will have an opportunity to revise the estimated total project cost (in man days), and to revise your desired staff level.

-Make your changes to the cost estimate and the desired staffing level both on the documentation sheet provided and on the screen.

A LAB ATTENDANT MUST VERIFY YOUR FINAL RESULTS!

- GOOD LUCK! Press <ENTER> to continue.

FIGURE 2-1 Introductory Screen

or accept the previous level (which is the default), and input a new estimated project cost (in man days) or accept the previous value (default).

Once these values are input or accepted, and entered on a data documentation sheet provided to each player, the game prompts the player to continue to the simulation of the next interval. The game continues until the project is complete in terms of development and testing, and indicates the time (schedule) and cost (man days) of completion. Players are under no staffing level or project cost **estimate** constraints, although they are reminded before the game begins of the need

PROJECT STATUS REPORT

ELAPSED TIME = = = = = = = = => 40 Days

ESTIMATES MADE AT THE START OF THE PROJECT

Project Size	396 Tasks
Project Cost in Man Days	1,111 Man Days
Project Duration	320 Days
PROJECT STATUS at Time = = = = = = = =>	40 Days
Updated Estimate of Total Project Size	396.50 Tasks
Development(Design & Code) Reported Complete	12.84 Percent
% Testing Reported Complete	0.00 Percent
Updated Estimate of Total Man Days	1,111 Man Days
Total Man Days Expended to date	164.17 Man Days
Updated Est. of Project Duration (start-end)	229 Days
Current Staff Size	4.5 Fulltime Staff

PRESS <ENTER> TO RETURN TO MENU

FIGURE 2-2 PROJECT STATUS REPORT

to remain as close as possible to the budgeted schedule and cost.

The actual experiment consisted of two different SDM models, both of which were based on a NASA experiment which has been used as a basis for other research efforts. By using real data from real projects, we can measure and compare the results of the experiment to a known baseline based on reality. Subjects were divided randomly into two groups. Group GRADUAL was directed to run the 'EXP1' program, in which they were presented with a simulated software project that grew gradually in size from 320 tasks (a task being equal to approximately 50 lines of code) to 610 tasks by day 100.

Group ABRUPT players ran the 'EXP2' program, in which they managed a project which remained the same size (320 tasks) through the 100th day of the simulation; after the Day 80 status report, the players received a message on the screen alerting them that due to increased requirements, the project size had just increased to 610 tasks. After this point, the estimated size of the project remained the same (at 610 tasks).

The motivation in each case was the same; the subjects were told that their participation in the experiment would be rewarded with extra credit points in the Software Engineering course they were taking. Although the number of points they would receive was not linked to their performance, they were told that their objective was to complete the project as close as possible to the original estimates of schedule and cost. These original estimates appeared at the top of the status report for each time interval.

Two days prior to the conduct of the actual experiment, each subject received an initial 45-minute briefing regarding their objectives in the experiment, possible ways of interpreting the status reports, and advice regarding the reliability of estimates in software projects. Prior to the actual experiment, each subject performed a trial run simulation called TEST on an individual basis; the design and documentation is discussed later in this chapter. The purpose of these training and orientation sessions was to eliminate

discomfort or unfamiliarity with the interface and the game. The TEST simulation revealed no increase in size of the project, nor did it allow the simulation to run beyond the 80-day interval, in order to preclude advance knowledge or bias of the actual experiment. Each subject thus played the TEST simulation for two 40-day periods, then exited the TEST program and initiated the EXP1 or EXP2 program, depending on their group.

B. THE SOFTWARE

In order to construct the experiment, the gaming interface of the SDM model had to be tailored to the experimental design, and explanatory documentation developed to outline the background, instructions, tasks, rules and other considerations to the subjects.

The interface includes the Dynamo simulation files and Dynex files, which allow the model designer to interface with the simulation language and construct the experimental design. Once complete, the interface is transparent to the experimental subject, who simply starts and plays the 'game' without knowledge of the workings of the simulation itself. Further, the interface must include the means for capturing the raw data obtained from each subject's decisions for further analysis.

The language interface that the designer of the experiment uses is called Dynex. Through the use of any text editor, the

Dynex (or DNX) file is created to perform the following functions: display information to the player identifying what the player needs to do, capture the variables input by the player required for the simulation, and provide a format for the output (status report) screens. Copies of the TEST, EXP1 and EXP2 Dynex files and their associated screens are in Appendices A, B, and C, respectively.

The interface is controlled by a batch (BAT) file of the same name, which invokes the interface, provides instructions after each simulation is completed, invokes the display of the status report or the initiation of the next set of player inputs and provides overall 'play-by-play' control of the game's events. Copies of the TEST, EXP1, and EXP2 batch control files are in Appendices D, E, and F, respectively.

C. THE DOCUMENTATION

Each subject received a set of instructions which describes the background, scope and procedures for the gaming interface. This documentation gives the subject a clear understanding of his/her role in the experiment, explains the status report screens (an example is shown in Figure 2-2), and presents procedures for running the TEST simulation as well as unique instructions for the specific experimental version. The background and instructions were the same for both groups; the only difference in the documentation was the batch filename (EXP1 or EXP2) in the EXPERIMENT portion of the

instructions that the subject is directed to enter once the TEST simulation is completed.

This documentation was provided to each subject prior to moving to the computer laboratory for the TEST simulation and actual experiment. It was thoroughly discussed, and all questions about its contents were answered before any subjects began the experiment. The subjects were directed verbally and in the instructions to run the TEST simulation first, and were told not to write any estimates or staffing decisions down while running TEST. As previously stated, the TEST simulation mirrored the actual experiments, without revealing their content or nature. The TRIAL RUN and EXPERIMENT instructions portion of the documentation gave each subject step-by-step directions and the unique batch filename for initiating their particular experiment (EXP1 or EXP2) once they stopped the TEST simulation after two time periods (80 days). A copy of the documentation and instruction set is in Appendix G.

The final page of the documentation, the staffing level and project cost estimate record sheet, provides the researcher a means of capturing the staffing level and cost estimate decisions made by each subject. This page identifies the initial estimates of the size (396 tasks, where a task is approximately 50 lines of code), cost (1,111 man days) and duration (320 days) of the project, as well as the size of the initial core team (5 people). It also specifies when a project is considered 'complete' (when "% Reported Complete"

equals 100 for both Development (Design and Coding) and Testing), and provides blank spaces for project cost estimates and staffing level decisions to be recorded by the subject for each time period. A copy of this record sheet is in Appendix H.

D. THE TRIAL EXPERIMENT

Once the gaming interface and documentation were prepared, trial experiments were conducted to provide feedback on potential design or procedural problems. Four students who had knowledge of personal computers were selected to play the 'game' as trial experiments. The objective of the trial experiment was to measure the individuals' interaction with the gaming interface and the documentation. Additionally, these students would become laboratory assistants for the conduct of the actual experiment, so their participation in the trial experiment served to give them hands-on experience with the experiment and the interface itself. Specific concerns to be examined in the trial experiment were:

- Are the instructions clear?
- Are the subjects comfortable with the gaming interface?
- How long does the experiment take?
- What are the questions the researcher and lab assistants need to be prepared to answer?
- Two of the subjects of the trial experiment used the EXP1 gaming interface (gradual increase in size), while the other two subjects used the EXP2 interface (sudden change

in requirements). Two subjects were not provided a trial run while the other two subjects used the TEST simulation before going on to the actual experimental versions. Pertinent observations and lessons learned were:

- Average time for the experiment was 45 minutes, including instruction review, simulation, and saving information to disk. Inclusion of the TEST simulation added approximately 10 minutes to the experiment's duration.

- The first two subjects, who did not have the TEST trial run, expressed a need for one, saying that they had thought that the first two time periods were a trial run. They also said that the trial run's start and finish should be clearly delineated in the written and on-screen directions, to preclude confusion. The two subjects who ran the TEST simulation felt more comfortable with the actual experiment than the two who had not, and had no problems transitioning from the TEST simulation to the actual experimental version.

- One subject expressed a need for scrap paper on which to perform calculations. Although the scrap paper was provided, all subjects in the actual experiment were told to rely on their judgement as opposed to standard metrics, such as COCOMO.

- Heuristics and metrics techniques presented in the ongoing Software Development class from which all of the subjects came were a stumbling block for two of the four subjects. The information presented in the initial estimates and the status reports conflicted with what the course had taught them to expect. They recommended that reliance on judgement, rather than metrics, be stressed in the initial briefing and during the conduct of the experiment.

- One of the subjects, who ran the EXP2 simulation (sudden increase in size), did not react at first to the change, as he thought it was caused by something he had done. To remedy this, the warning screen alerting the subject to the change in requirements was made larger, and preceded by a notice to pay attention to the next screen.

- Computers equipped with a math coprocessor and/or 80386 microprocessors performed the simulations and provided faster response to subjects than those machines not so equipped. To reduce the response time as much as possible, only computers with hard drives would be used, and, to the extent possible, only those equipped with math coprocessors and/or 80386 microprocessors.

E. FINAL PREPARATIONS

The changes noted in the lessons learned were implemented in the gaming interface and documentation, and the initial briefing included the emphasis on individual judgement rather than metrics. Group GRADUAL was defined as the group of subjects that would 'play' the EXP1 (gradual size increase) simulation, while Group ABRUPT would be the group of subjects using the EXP2 (sudden size increase) simulation. As indicated before, the difference in the simulations occurred within the Dynex control file, and was transparent to the subject.

The final copies of the documentation for the two groups differed only in the batch filename that was provided to start the actual experiment; all other guidelines, information and record sheets were identical. A folder was prepared for each subject; it included a copy of the documentation, scrap paper, a survey addressing the subject's academic and work experience, and a diskette that contained the TEST and appropriate experimental version (EXP1 or EXP2) simulation programs. Additional preparations included assuring the availability of the computer laboratories, ascertaining individual computer status, loading of required files on the hard drives of the computers and preparing schedules and seating charts.

III. CONDUCTING THE EXPERIMENT

A. TASKS AND PROJECT CHARACTERISTICS

The research subjects, having received the initial briefing two days prior to the actual experiment, were familiar with the skills expected of a software project manager. Experiencing the TEST simulation trial run immediately prior to the actual experiment ensured that they were familiar with the gaming interface itself.

The two experiment simulation scenarios, EXP1 and EXP2, were designed to allow the experimental subjects to make two decisions for each 40-day time period, based on the initial information and status reports they received from the simulations, until the completion of the project. The first decision they were prompted to make was to update the project's total cost estimate (in man days). The second decision was to determine a desired staffing level for the rest of the project. The project manager's role was stressed as that of resource manager; allocating resources as necessary to complete the project on time and within the projected budget, as close as possible to the original estimates.

Subjects used the gaming interface to enter their decisions for each time period, and were provided with a status report. This report was designed in a text format,

which also allowed the data in each status report, as well as the final cost and schedule data for each subject, to be captured by the interface. In this fashion, staffing and cost estimate decisions were captured by the interface as well as on the subject-completed record sheet.

B. ORGANIZING THE EXPERIMENT

The experimental setting consisted of a 15-minute classroom training session in which the documentation, seating assignments and guidelines were presented and questions resolved. Due to the size of the groups and the limited number of acceptable computers within each laboratory, two different laboratories were used, with one laboratory assistant in each. The assistants answered general questions about the procedure or gaming interface, but did not answer questions about the actual decisions to be made. When asked about relative importance of schedule or cost, the assistants merely reiterated the guidance contained in the documentation; as close as possible to the original estimates of schedule and budget. The subjects received their individual folders at the beginning of the training session, and were directed to their respective seating locations once in the laboratories. In order to avoid inadvertent sharing of status report or other information, the seating ensured alternation of Group GRADUAL and Group ABRUPT players in the laboratory. Additionally, subjects were instructed to perform their own work and

informed that since several versions of the simulation were being used, anyone else's data or decisions could be misleading. Each laboratory assistant had a full set of backup diskettes and instructions so that any problem could be immediately resolved, and backup computers were designated on the seating chart in the event of a system malfunction.

C. THE SAMPLE POPULATION

The subjects for this experiment were students from a graduate level software engineering and management course, IS-4300, at the Naval Postgraduate School in Monterey, California. The course was divided into two sections; Segment 1 consisted of 28 students, and Segment 2 consisted of 27 students. After the names of the researcher and the laboratory assistants were removed from the course rosters, the following matched sample procedure was followed to randomize the sample population and assign them to experimental groups [Ref. 6].

A two-level randomization was perfomed using an alphabetical list of students in each segment and a standard table of random digits [Ref. 7]. The population randomizing worksheet used for each section is at Appendix I. Column A is the alphabetical list of the students in each section; Column B is a two-digit random number taken from the standard table of random numbers and assigned to each student. The random numbers for Segment 1 were assigned beginning with row 20 of

the table; random numbers for Segment 2 were assigned beginning with row 14. The list of students for each segment was then sorted into ascending order of random number. This randomized the alphabetical list in the first level (Column C). These first level randomized lists were then assigned random numbers from the table; Segment 1 with numbers beginning with row 9, and Segment 2 with numbers beginning with row 37 of the table (Column D). This list was again sorted into ascending order of random number, randomizing the original alphabetical list to the second level (Column E); this list was then used to make assignments to Groups GRADUAL and ABRUPT by alternating the group assignments (Column F).

A total of 50 subjects were scheduled to participate in the experiment; 25 in each group. One subject was ill and unable to participate, so was dropped from the sample population. One subject, in 'playing' the game, misunderstood the instructions and repeatedly pressed the numeric key "1" instead of entering his desired staffing level, thereby nullifiying his decisions; he was also dropped from the sample population. These students are designated in Appendix I by the shading of their names. Both had been assigned to the GRADUAL Group, so the final sample populations used in the experiment consisted of 23 subjects in Group GRADUAL and 25 subjects in Group ABRUPT.

D. DEPENDENT MEASURES

Under certain sequences the Dynamo gaming interface does not allow some projects to reach design and testing completion of 100 percent; the simulation signifies completion by repeating status report information and showing an elapsed time that is not a multiple of the 40 day period, with only about 97 percent completion of design and testing. The general heuristic used to verify simulation completion was the observance of the 97 percent completion report and the irregular elapsed time figure.

1. Process Variables

The first process dependent variable was the project cost estimate made by each subject at the end of each time period. The line on the Status Report Screen from Appendix E which reads "Updated Estimate of Total Man Days" mirrors the cost estimate made by the subject for that time interval.

The second process dependent variable collected as a point of comparison was the actual staffing level decisions made by each subject at the end of each time interval. This variable was not reflected in the Status Report. Each subject decided on and recorded staffing level needs on the documentation sheet before entering them into the computer.

2. Performance Variables

The subjects' performance was operationalized in terms of three variables: cost, schedule and combined cost and schedule.

The first dependent variable measured as an output of the simulation was final cost. The line on the Status Report Screen in Figure 2-2 which reads "Total Man Days Expended to Date" is the cost of the project at the end of the given reporting period; upon completion of the simulation, this value is compared with the original project cost, and the dependent variable DIFFCOST is calculated as a percentage deviation from the original project cost [(COST + ORIGINAL COST) / ORIGINAL COST] represents the final project cost.

The second dependent variable measured as an output of the simulation was the final schedule. The line on the Status Report Screen from Appendix E which reads "Elapsed Time" specifies the final schedule upon completion of the simulation. This value is compared with the original project schedule, and the dependent variable DIFFSKED is calculated as a percentage deviation from the original project schedule [(SCHED + ORIGINAL SCHED) / ORIGINAL SCHED].

The third performance dependent variable COSTSKED was the average combined difference from the original estimates of cost and schedule [DIFFCOST + DIFFSKED) / 2].

IV. EXPERIMENTAL RESULTS AND ANALYSIS

A. PREPARATORY ANALYSIS

1. Model of Analysis

The raw experimental data produced a final cost and schedule for each project manager, as well as their staffing level and cost estimate decisions for each time interval. Analysis of the data is based on the comparison of decisions and performance between the two groups, GRADUAL (gradual increase in project size) and ABRUPT (sudden increase in project size).

The SAS General Linear Models (GLM) procedures were used for Univariate and Multivariate Analyses of Variance and for Repeated Measures analysis due to the inequal populations involved (22 subjects in the GRADUAL Group, 25 subjects in the ABRUPT Group). The raw data is presented in Appendix J as the data portion of the SAS control files; it includes the name of the subject, his/her group (GRADUAL or ABRUPT), and the individual's final schedule and final cost.

2. Subjects

a. Student Grade Distribution

Students were randomly assigned to either of two groups as described in a previous chapter. There were no

significant differences between the two groups with respect to student ability, as reflected in their end of course grades (Sig of F = 0.3497).

b. Outliers

Preliminary SAS data analysis was performed on the raw data, and revealed one subject whose final cost did not fall within three standard deviations of the mean COST (three standard deviations is accepted by statistical texts as representing 99% of the observations). The subject's process and performance data was therefore excluded from all analyses, resulting in a total of 22 GRADUAL Group subjects and 25 ABRUPT Group subjects.

B. PROCESS MEASURES ANALYSIS AND RESULTS

Following the approach suggested by Winer [Ref. 7], multivariate analysis of variance for repeated measures analyses were performed on staffing level and cost estimate decisions. The staffing level decision data for comparison of the GRADUAL and ABRUPT Groups are in Appendix K, in the data section of the SAS control file. The project cost estimate decision data for Groups GRADUAL and ABRUPT are in Appendix L, in the data section of the SAS control file.

1. Staffing Level Decisions

The mean staffing level decisions for each time period by group are plotted in Figure 4-1. The patterns of staffing decisions identified in Figure 4-1 support Hypothesis 1a.

As a group, those subjects presented with a sudden increase in project size (ABRUPT Group) reacted quickly by increasing staff levels by a significantly larger amount than the group experiencing a gradual increase in project size. Additionally, the trend after the initial increase was one of gradually declining levels, and an earlier completion date (schedule).

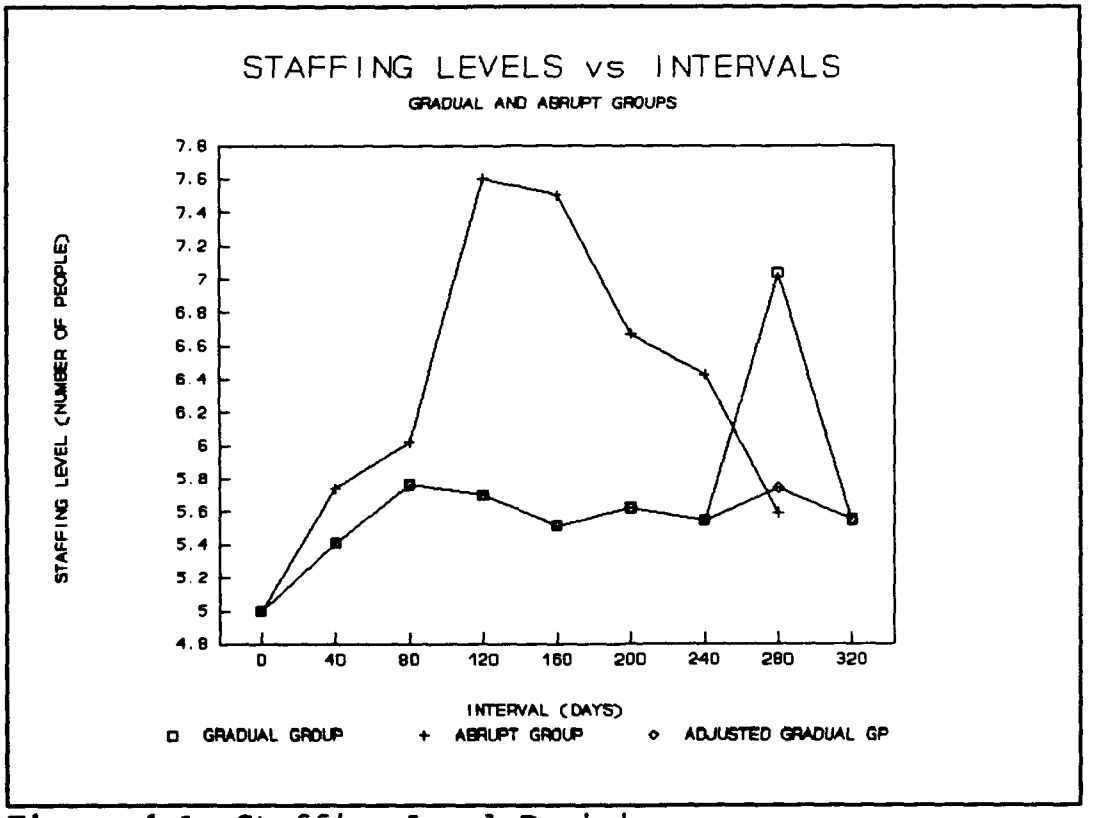

Figure 4-1 Staffing Level Decisions

In contrast, the GRADUAL Group means reflect a sharp increase in staff levels through the second time period (day 80), a slight decrease for two time periods, a slight rise and

fall in the next two time periods, and then a drastic increase at Day 240, followed by an equally drastic decrease at Day 320. Analysis of the raw data for Day 280 revealed a reduced number of observations being averaged, five of the subjects having already completed the project. Additionally, one subject's staffing level decision (29 people) at Day 280 skewed the entire curve. His rationale for this sudden increase was, "I was close to the scheduled completion date, and was behind in tasks reported complete, so I doubled my staffing level." The "ADUSTED GRADUAL GROUP" curve on the graph shows the effect of his decision by omitting his decision value from the computation of the interval's mean staffing level. The staffing level curve then continues its slight increase/decrease tendency which began at Day 160 through the final interval (Day 320). The mean completion date for Group GRADUAL was approximately forty days later than that of Group ABRUPT, as indicated by the endpoints of the graph.

Results from the multivariate analysis of variance performed on staffing level decisions shown in Table 4-1 further support Hypothesis 1a. They show that the overall staffing patterns of subjects across the two groups were significantly different across time ($P < 0.05$). There was no significant between subjects effect; overall decisions of subjects were not significantly different across the two groups ($P > 0.1$). The Within Subjects results of the MANOVA

shown in Table 4-1 support the findings of the previous paragraph. The MANOVA shows significant INTERVAL effect

TABLE 4-1 SUMMARY OF STAFFING LEVEL DECISIONS REPEATED MEASURES ANALYSIS[1]

SOURCE OF VARIATION	s.s.	d.f.	F	Sig of F
BTWN SUBJ				
Group	24.4489	1	2.26	0.1398
Subj w/in Group	453.3894	42		
W/IN SUBJ				
Interval	0.7426	5,38	2.6343	0.0386
Intvl*Grp	0.6612	5,38	3.8936	0.0060

($P < 0.05$), indicating that all subjects made different decisions as time evolved. In addition, the interaction, or INTERVAL*GROUP effect is significant ($P < 0.05$), indicating that the pattern of the decisions made differed significantly over time between the two groups.

2. Subjects' Cost Estimate Decisions

The mean cost estimates for each time period by group are plotted in Figure 4-2. The project cost estimates for each of the 47 subjects are presented in Appendix L as the data section of the SAS control file. Cost estimate decision

[1]Degrees of freedom are reduced because of the number of observations ignored by the Repeated Measures analysis due to missing values (subjects had already completed the project).

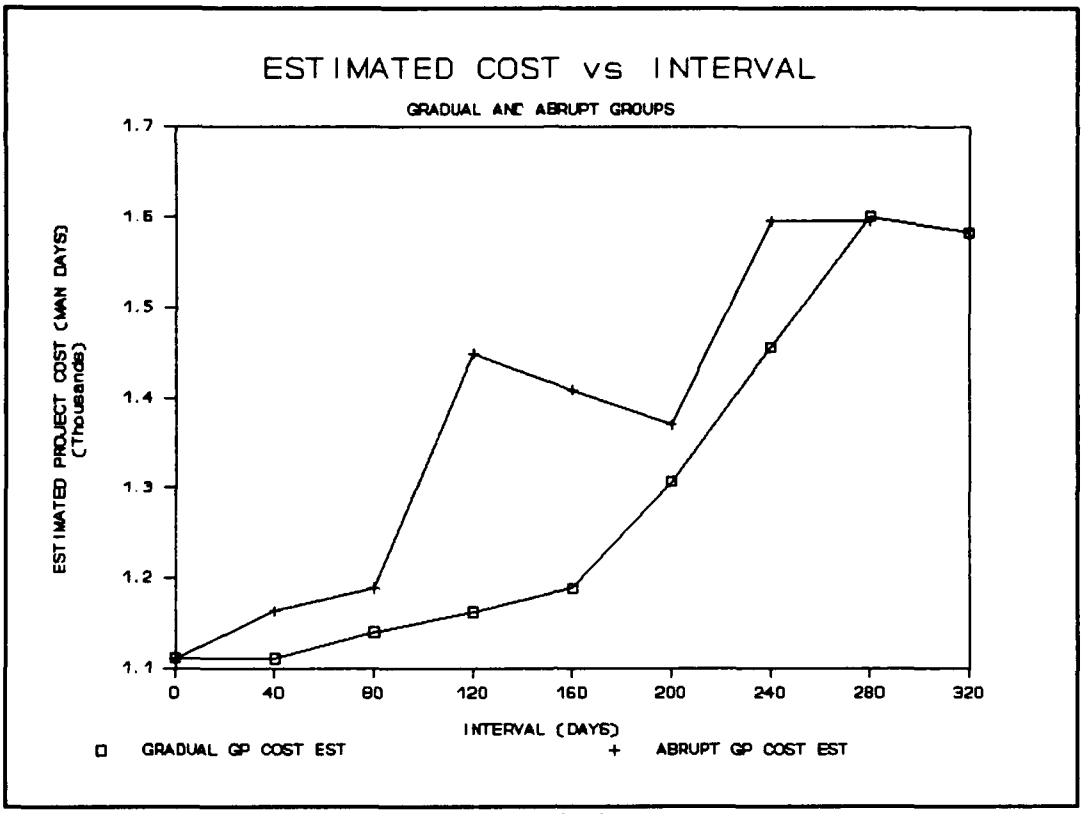

Figure 4-2 Cost Estimate Decisions

patterns identified by the graph support Hypothesis 1b.

The mean cost estimates for each group closely parallel each other until after Day 80, when the ABRUPT Group mean estimate jumps sharply while the GRADUAL Group mean continues a smooth climb. This reflects the sudden change in project size just revealed to the ABRUPT Group managers. After the initial sharp increase, the ABRUPT Group managers lower their estimates for two time periods in a row, just as the GRADUAL Group managers begin to increase the rate of their estimate growth. At Day 200, both groups increase their estimates, presumably in response to the advent of the

scheduled completion date in three time periods. However, GRADUAL Group maintains a consistent increase while ABRUPT Group increases their estimates sharply, as they had after Day 80, and then holds the estimate steady for the final time period. The pattern revealed in this figure shows a smooth, consistent increase in the GRADUAL Group estimate, while the ABRUPT Group is characterized by abrupt, spiky increases and decreases. While the response of the ABRUPT Group to the sudden increase in project size at Day 100 is obvious, the reason for the similar increase at Day 200 is less so.

Results from the multivariate analysis of variance performed on cost estimate decisions shown in Table 4-2 further support Hypothesis 1b showing that the overall cost

TABLE 4-2 SUMMARY OF COST ESTIMATE DECISIONS REPEATED MEASURES ANALYSIS[2]

SOURCE OF VARIATION	s.s.	d.f.	F	Sig of F
BTWN SUBJ				
Group	2238451.4	1	6.31	0.0160
Subj w/in Group	14908267	42		
W/IN SUBJ				
Interval	0.3026	5,38	17.5114	0.0001
Intvl*Grp	0.7083	5,38	3.1296	0.0184

[2]see Footnote 1.

estimate patterns of subjects across the two groups were significantly different across time ($P < 0.05$). There was a significant between subjects effect; within a given interval, the values differed significantly between groups ($P < 0.05$)

The Within Subjects results of the MANOVA shown in Table 4-2 support the findings of the previous paragraph. The MANOVA shows significant INTERVAL effect ($P < 0.05$), indicating that all subjects made different decisions as time evolved. In addition, the interaction, or INTERVAL*GROUP effect is significant ($P < 0.05$), indicating that the pattern of the decisions made differed significantly over time between the two groups.

C. PERFORMANCE MEASURES ANALYSIS AND RESULTS

This area of comparison involves the final cost and schedule for each group (Groups GRADUAL and ABRUPT) as a whole. Table 4-3 shows the means and standard deviation of DIFFCOST, DIFFSKED and COMBINED DIFF. These values show that GRADUAL Group (gradual increase in project size) has a higher mean value for DIFFSKED, indicating that they were farther from the initial estimated schedule than the ABRUPT Group (sudden increase in project size), and a lower mean value for DIFFCOST, indicating they were closer to the original cost estimate than the ABRUPT Group. The ABRUPT Group had a lower combined difference mean, indicating that, on average, they were closer to the original estimates than the GRADUAL Group.

The recurring theme, however, is that regardless of **how** the change was presented, budget was forsaken in favor of meeting the schedule.

Results of the MANOVA performed on DIFFCOST and DIFFSKED are shown in Table 4-4. They suggest that there was a significant difference in performance between the two groups if a 0.10 level of significance is applied for rejecting the

TABLE 4-3 PROJECT COST AND SCHEDULE MEANS AND STANDARD DEVIATION BY GROUP

Group	Variable	**MEAN**	**STD DEV**
GRADUAL	DIFFCOST	0.4736	0.1105
	DIFFSKED	0.0145	0.1513
	COMBINED DIFF	0.2441	0.0819
ABRUPT	DIFFCOST	0.4962	0.0908
	DIFFSKED	-0.0930	0.1607
	COMBINED DIFF	0.2016	0.0752

hypothesis. If a more strict 0.05 level is applied, however, the null hypothesis cannot be rejected. The results suggest moderate, but not strong support for hypothesis 2.

TABLE 4-4 MULTIVARIATE ANALYSIS OF VARIANCE FOR SCHEDULE AND COST

Lambda	df(num)	df(den)	F	Sig of F
0.8846	2	45	2.94	0.0634

The results of the univariate analysis of variance for DIFFSKED in Table 4-5 support Hypothesis 2 in terms of schedule ($P < 0.05$). However, the results of the univariate analysis of variance for DIFFCOST do not support Hypothesis 2 in terms of cost performance ($P > 0.05$). A univariate analysis of variance was also performed on the combined

TABLE 4-5 UNIVARIATE ANALYSIS OF VARIANCE OF COST, SCHEDULE AND COMBINED DIFFERENCE

VARIABLE	s.s.	d.f.	F	Sig of F
DIFFCOST	0.0042	1	0.15	0.7042
DIFFSKED	0.1135	1	4.53	0.0387
COMBINED	0.0403	1	4.65	0.0363

differences from the original estimates, COMBINED. Results of this analysis are also displayed in Table 4-5, and indicate strong support for Hypothesis 2 ($P < 0.05$).

V. CONCLUSIONS

A. SUMMARY OF FINDINGS

The single-project experiment was conducted using a properly randomized sample population, verified by statistical analysis of grade distribution of the the subjects in their assigned groups. The population was examined for outliers that would skew the results; one was detected and deleted from results analysis. The specific findings of the experiment are described below. The measure of performance is defined as the ability of each project manager to meet the original estimates of time and schedule.

- Project managers of a system which roughly doubles in size during its lifecycle make different decisions on staffing and cost estimates when given the change abruptly than when presented with the change in gradual increments.
- Project managers of a system which roughly doubles in size during its lifecycle perform better in terms of cost and schedule when given the change abruptly than when presented with the change in gradual increments.

In all cases, the deviation of the final schedule from the original schedule was less than the deviation of the final cost from the original cost, indicating that if sufficient staff resources are available, managers will jeopardize maintaining budget goals in order to achieve a given schedule.

The decision trends of the groups indicate that the GRADUAL groups reacted more slowly to the changes in size, using fewer resources initially and increasing both staff size and cost estimates rapidly near the end of the lifecycle. The ABRUPT group displayed a tendency to use greater resources upon learning of the change in size, and decreasing staff size and cost estimates near the end of the lifecycle.

B. IMPLICATIONS

Use of resources depends as much on the knowledge of when and how many resources will be required as on the knowledge of the task to be performed. Although our knowledge of a project's complexity and/or size may be imperfect, the more information we have about the scope of the project early on, and about its actual progress will improve the performance and efficiency of the project. Although the reactions of the ABRUPT group were more pronounced than those of the GRADUAL group, the end result was improved performance in terms of schedule, if not cost as well.

C. FUTURE RESEARCH EFFORTS

System dynamics and its effects on project management are of crucial importance in understanding and improving processes and performance. Use of the SDM gaming interface to investigate the effects of improved visibility, estimates and reporting procedures lends itself to several research efforts.

A logical followup to this experiment would be to examine the effects of improved visibility at early-, mid- and late-intervals in the lifecycle of the project to determine where it is crucial, where it is helpful, and where it is deleterious to the success of the project.

APPENDIX A: TEST DYNEX FILE

```
if #tm<0.9 then
display clear

          *********  EXPERIMENT TRIAL RUN *********

              Important Points to Remember !!!!!!!!!
              ***************************************

    - You are not allowed to discuss this exercise with anyone
other than a lab attendant.  Please refrain from discussing
this with other class members until they have completed the
project.
    - The system will run through the first simulation period
(2 months) and provide you with a status report.  At the end
of each reporting period, you will have an opportunity to
revise the estimated total project cost (in man days), and to
revise your desired staff level.
    - In this trial run, you do not have to annotate the
documentation sheet.  Use the trial run for two time periods
to familiarize yourself with the experiment procedures.

    - Press <ENTER> to continue
dendq
choice 1
cend 1/1
else

choice 1
cend 1/1
display clear

       INPUT YOUR ESTIMATE OF THE TOTAL PROJECT COST IN MAN
DAYS

************************************************************


       1)  Press <ENTER> to maintain your last cost estimate

                        *****  OR  *****

       2)  Enter your new estimate of total project cost (in
man days)
           and press <ENTER>.
```

Your last project cost estimate was =
dendq
dq TOTMD1=0<100000
display clear

!!!!!!!! WARNING !!!!!!!!
Make sure that you have written your project cost estimate down on the project documentation sheet before continuing with the simulation.

This is your final chance to change your estimated total project cost. Press <ENTER> to keep the same estimate or enter a new cost estimate and then press <ENTER>.

The updated estimate of total project cost is =
dendq
dq TOTMD1=0<100000
display clear

INPUT YOUR DESIRED STAFFING LEVEL
****

1) Press <ENTER> to maintain your last desired staffing level.

********* OR *********

2) Enter the new desired staffing level and press <ENTER>.

Your last desired staffing level was =
dendq
dq WFS1= 0<100
display clear

|----------|
!!!!!WARNING!!!!!

Make sure that you have written your staffing level decision down on the project documentation sheet before continuing with the simulation.

```
    This is your final chance to change your
   staffing level for this time period.  Press
   <ENTER> to keep the same number or enter a
   new staffing level and press <ENTER>.

|-----------------------------------------------------------|
The current staffing level =
dendq
dq WFS1= 0<100
end
display clear
        Press <ENTER> to simulate the next time interval.
dendq
choice 1
REPORT
time=maxtime,
FORMAT="40-"
"PROJECT STATUS REPORT";;
Format="20<,54<,66<",PICTURE="Z,ZZ9V"
"ELAPSED TIME  = = = = = = = = =>",tm,"Days";;
Format="5<"
"ESTIMATES MADE AT THE START OF THE PROJECT";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZZV"
"Project Size",IPRJSZ,"Tasks";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZZV"
"Project Cost in Man Days",TOTMD0,"Man Days";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZZV"
"Project Duration",TDEV1,"Days";
Format="5<,52<,66<",PICTURE="ZZZ,ZZ9V"
"PROJECT STATUS at Time = = = = = = = = = = = =>",tm,"Days";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V.99"
"Updated Estimate of Total Project Size",PJBSZ,"Tasks";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V.99"
"%    Development    (Design    &    Code)    Reported
Complete",PDVRC,"Percent";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V.99"
"% Testing Reported Complete",PTKTST*100,"Percent";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V.99"
"Updated Estimate of Total Man Days",JBSZMD,"Man Days";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZZV.99"
"Total Man Days Expended to date",CUMMD,"Man Days";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V"
"Updated Est. of Project Duration (start-end)",SCHCDT,"Days";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V.9"
"Current Staff Size",FTEQWF,"Fulltime Staff";
FORMAT="5<"
  "PRESS <ENTER> TO RETURN TO MENU"
cend 1/1
spec md_length=#length+40
```

APPENDIX B: EXP1 DYNEX FILE

```
if #tm<0.9 then
display clear

                Important Points to Remember !!!!!!!!!
                ***************************************

    - You are not allowed to discuss this exercise with anyone
other than a lab attendant.  Please refrain from discussing
this with other class members until they have completed the
project.

    - The system will run through the first simulation period
(2 months) and provide you with a status report.  At the end
of each reporting period, you will have an opportunity to
revise the estimated total project cost (in man days), and to
revise your desired staff level.

     -Make your changes to the cost estimate and the desired
staffing level both on the documentation sheet provided and on
the screen.

      A LAB ATTENDANT MUST VERIFY YOUR FINAL RESULTS!

    - GOOD LUCK!     Press <ENTER> to continue.
dendq
choice 1
cend 1/1
else

choice 1
cend 1/1

display clear

       INPUT YOUR ESTIMATE OF THE TOTAL PROJECT COST IN MAN
DAYS

************************************************************

     1)  Press <ENTER> to maintain your last cost estimate

                    ********  OR  ********
```

2) Enter your new estimate of total project cost (in man days)
and press <ENTER>

Your last project cost estimate was =
dendq
dq TOTMD1=0<100000
display clear

!!!!!!!! WARNING !!!!!!!!

Make sure that you have written down your project cost estimate down on the project documentation sheet before continuing with the simulation.

This is your final chance to change the estimated total project cost. Press <ENTER> to keep the same estimate or enter a new cost estimate and then press <ENTER>.

The updated estimate of total project cost is =
dendq
dq TOTMD1=0<100000
display clear

INPUT YOUR DESIRED STAFFING LEVEL
****

1) Press <ENTER> to maintain your last desired staffing level.

********* OR *********

2) Enter the new desired staffing level and press <ENTER>.

Your last desired staffing level was =
dendq
dq WFS1= 0<100
display clear

|----------|
!!!!!WARNING!!!!!

Make sure that you have written your staffing

```
  level decision down on the project documentation
  sheet before continuing with the simulation.
    This is your final chance to change your
  staffing level for this time period.  Press
  <ENTER> to keep the same number or enter a
  new staffing level and press <ENTER>.

|-----------------------------------------------------------|
    The current staffing level =
dendq
dq WFS1= 0<100
end
display clear
        Press <ENTER> to simulate the next time interval.
dendq
choice 1
REPORT
time=maxtime,
FORMAT="40-"
"PROJECT STATUS REPORT";;
Format="20<,54<,66<",PICTURE="Z,ZZ9V"
"ELAPSED TIME  = = = = = = = = =>",tm,"Days";;
Format="5<"
"ESTIMATES MADE AT THE START OF THE PROJECT";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZZV"
"Project Size",IPRJSZ,"Tasks";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZZV"
"Project Cost in Man Days",TOTMD0,"Man Days";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZZV"
"Project Duration",TDEV1,"Days";
Format="5<,52<,66<",PICTURE="ZZZ,ZZ9V"
"PROJECT STATUS at Time = = = = = = = = = = =>",tm,"Days";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V.99"
"Updated Estimate of Total Project Size",PJBSZ,"Tasks";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V.99"
"%    Development    (Design    &    Code)    Reported
Complete",PDVRC,"Percent";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V.99"
"% Testing Reported Complete",PTKTST*100,"Percent";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V.99"
"Updated Estimate of Total Man Days",JBSZMD,"Man Days";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZZV.99"
"Total Man Days Expended to date",CUMMD,"Man Days";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V"
"Updated Est. of Project Duration (start-end)",SCHCDT,"Days";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V.9"
"Current Staff Size",FTEQWF,"Fulltime Staff";
FORMAT="5<"
  "PRESS <ENTER> TO RETURN TO MENU"
cend 1/1
spec md_length=#length+40
```

APPENDIX C: EXP2 DYNEX FILE

```
if #tm<0.9 then
display clear

                    Important Points to Remember !!!!!!!!!
                    ***************************************

    - You are not allowed to discuss this exercise with anyone
other than a lab attendant.  Please refrain from discussing
this with other class members until they have completed the
project.

    - The system will run through the first simulation period
(2 months) and provide you with a status report.  At the end
of each reporting period, you will have an opportunity to
revise the estimated total project cost (in man days), and to
revise your desired staff level.

    - Make your change to the desired staffing level both on
the   documentation sheet provided and on the screen.

      A LAB ATTENDANT MUST VERIFY YOUR FINAL RESULTS!

    - GOOD LUCK!     Press <ENTER> to continue.
dendq
choice 1
cend 1/1
else

choice 1
cend 1/1
display clear

INPUT YOUR ESTIMATE OF THE TOTAL PROJECT COST IN MAN DAYS

*************************************************************


       1)  Press <ENTER> to maintain your last cost estimate

                          *****  OR  *****

       2)  Enter your new estimate of total project cost (in
man days)
           and press <ENTER>.
```

Your last project cost estimate was =
dendq
dq TOTMD1=0<100000
display clear

!!!!!!!! WARNING !!!!!!!!

Make sure that you have written your project cost estimate down on the project documentation sheet before continuing with the simulation.

This is your final chance to change your estimated total project cost. Press <ENTER> to keep the same estimate or enter a new cost estimate and then press <ENTER>.

The updated estimate of total project cost is =
dendq
dq TOTMD1=0<100000
display clear

INPUT YOUR DESIRED STAFFING LEVEL
****

1) Press <ENTER> to maintain your last desired staffing level.

********* OR *********

2) Enter the new desired staffing level and press <ENTER>.

Your last desired staffing level was =
dendq
dq WFS1= 0<100
display clear

!!!!!WARNING!!!!!

Make sure that you have written your staffing level decision down on the project documentation sheet before continuing with the simulation.

```
  This is your final chance to change your
staffing level for this time period.  Press
<ENTER> to keep the same number or enter a
new staffing level and press <ENTER>.

|-----------------------------------------------------------|

   The current staffing level =
dendq
dq WFS1= 0<100
if #tm <80 then
display clear
       Press <ENTER> to simulate the next time interval.
dendq
else
if #tm<120 then
display clear




  A     L     EEEEE   RRR     TTTTT   !
 A A    L     E       R  R      T     !!!
AAAAA   L     EEE     R RR      T     !!!
A   A   L     E       R  R      T      !
A   A   LLLL  EEEEE   R   R     T      o


    ****   SPECIAL REPORT FOLLOWS  ****

           PRESS <ENTER>, THEN READ CAREFULLY!


dendq
choice 1
cend 1/1
display clear

   ------------------------------------------------------------
```

```
!!!!!


        YOUR PROJECT SIZE JUST INCREASED BY 54%!


       THE PREVIOUS PROJECT SIZE WAS #PJBSZ TASKS

       THE CURRENT PROJECT SIZE IS 609 TASKS

            Press <ENTER> to continue . . .
```

```
dendq
choice 1
cend 1/1
display clear
      Press <ENTER> to simulate the next time interval.
dendq
else
end
end
end
display clear
       Press <ENTER> to simulate the next time interval.
dendq
choice 1
REPORT
time=maxtime,
FORMAT="40-"
"PROJECT STATUS REPORT";;
Format="20<,54<,66<",PICTURE="Z,ZZ9V"
"ELAPSED TIME  = = = = = = = = =>",tm,"Days";;
Format="5<"
"ESTIMATES MADE AT THE START OF THE PROJECT";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZZV"
"Project Size",IPRJSZ,"Tasks";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZZV"
```

```
"Project Cost in Man Days",TOTMD0,"Man Days";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZZV"
"Project Duration",TDEV1,"Days";
Format="5<,52<,66<",PICTURE="ZZZ,ZZ9V"
"PROJECT STATUS at Time = = = = = = = = = = = =>",tm,"Days";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V.99"
"Updated Estimate of Total Project Size",PJBSZ,"Tasks";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V.99"
"%    Development    (Design    &    Code)    Reported
Complete",PDVRC,"Percent";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V.99"
"% Testing Reported Complete",PTKTST*100,"Percent";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V.99"
"Updated Estimate of Total Man Days",JBSZMD,"Man Days";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZZV.99"
"Total Man Days Expended to date",CUMMD,"Man Days";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V"
"Updated Est. of Project Duration (start-end)",SCHCDT,"Days";
FORMAT="8<,52<,66<",PICTURE="ZZZ,ZZ9V.9"
"Current Staff Size",FTEQWF,"Fulltime Staff";
FORMAT="5<"
  "PRESS <ENTER> TO RETURN TO MENU"
cend 1/1
spec md_length=#length+40
```

APPENDIX D: TEST BATCH CONTROL FILE

```
echo off
CLS
init 1
GRAPHICS
bat /N /p /s
smlt TEST -go = -prs = -ls -ns -plm 6 -bw

-top dynex TEST -in TEST.STT -sc -ls -plm 6 -bw
        smlt TEST -gm = -ns -plm 6 -bw
        rep TEST -outf INTERVAL.OUT -t -bw >NUL
        rep TEST -bw >NUL
        infoofb 1
        Call -top1
        Exit
        goto -top%A

-top1   %A = 1
        color \1F
        ram
        cls
        begtype

                        MAIN MENU



   \1F            ENSURE YOU HAVE VIEWED THE PROJECT STATUS
REPORT
   \1F         FOR THIS TIME PERIOD PRIOR TO SELECTING OPTION
#2

                    \1D 1   \1F VIEW PROJECT STATUS REPORT

                    \1D 2   \1F PROCEED TO SIMULATE NEXT TIME
PERIOD

Choose an option:\1C DO NOT HIT <ENTER> AFTER SELECTION!!)  ;
end


-1stkey1 inkey %0 | if %0 # = 1 type %0;
        if %0 = key01b return
        goto -%0~1
```

```
-2ndkey1 inkey %1 | if %1 # = 1 type %1;
        if %1 = key01b return
        if %1 = key020 goto -$%0$1
        if %1 = key00d goto -$%0$1
        if %1 = key008 goto -top1
        if %1 = key14b goto -top1
        goto -%0%11

-1~1  **** VIEW PROJECT STATUS REPORT ********************
        rep TEST TEST -outf TEST.OUT -t -sc -ls -plm 6 -bw
        INKEY %0
        bat /p /s goto -top1

-2~1  **** PROCEED WITH NEXT SIMULATION *********************
       BAT CLS
       BAT COLOR \1F
       BAT BEGTYPE

*************************************************************


     1.  DETERMINE YOUR ESTIMATE OF TOTAL PROJECT COST (IN

         MAN DAYS) AND WRITE IT ON THE DOCUMENTATION SHEET.


     2.  DETERMINE YOUR DESIRED STAFFING LEVEL AND WRITE IT

         ON THE DOCUMENTATION SHEET.



     3.  PRESS <ENTER>.


*************************************************************;

END
bat /p /s goto -top

-%0~1
-$%0$1
-%0%11 beep goto -top1

-on.error-
 if %R > 82 if %R < 90 type !! Floating Point Error !! |goto
-Calc.
 Cls beep type Unexpected batch file error %R in line %L |exit
```

APPENDIX E: EXP1 BATCH CONTROL FILE

```
echo off
CLS
init 1
GRAPHICS
bat /N /p /s
smlt EXP1 -go = -prs = -ls -ns -plm 6 -bw

-top dynex EXP1 -in EXP1.STT -sc -ls -plm 6 -bw
        smlt EXP1 -gm = -ns -plm 6 -bw
        rep EXP1 -outf INTERVAL.OUT -t -bw >NUL
        rep EXP1 -bw >NUL
        infoofb 1
        Call -top1
        Exit
        goto -top%A

-top1   %A = 1
        color \1F
        ram
        cls
        begtype


\1A                          MAIN MENU


\1F          ENSURE YOU HAVE VIEWED THE PROJECT STATUS REPORT

\1F         FOR THIS TIME PERIOD PRIOR TO SELECTING OPTION #2


    \1D 1   \1F VIEW PROJECT STATUS REPORT

    \1D 2   \1F PROCEED TO SIMULATE NEXT TIME PERIOD

          Choose an option:\1C DO NOT HIT <ENTER> AFTER
SELECTION!!)  ;
end

-1stkey1 inkey %0 | if %0 # = 1 type %0;
        if %0 = key01b return
        goto -%0~1
-2ndkey1 inkey %1 | if %1 # = 1 type %1;
        if %1 = key01b return
        if %1 = key020 goto -$%0$1
```

```
        if %1 = key00d goto -$%0$1
        if %1 = key008 goto -top1
        if %1 = key14b goto -top1
        goto -%0%11

-1~1  **** VIEW PROJECT STATUS REPORT ********************
        rep EXP1 EXP1 -outf EXP1.OUT -t -sc -ls -plm 6 -bw
        INKEY %0
        bat /p /s goto -top1

-2~1  **** PROCEED WITH NEXT SIMULATION *********************
       BAT CLS
       BAT COLOR \1F
       BAT BEGTYPE


**************************************************************
*****

     1.  DETERMINE YOUR ESTIMATE OF TOTAL PROJECT COST (IN

         MAN DAYS) AND WRITE IT ON THE DOCUMENTATION SHEET.


     2.  DETERMINE YOUR DESIRED STAFFING LEVEL AND WRITE IT

         ON THE DOCUMENTATION SHEET.


     3.  PRESS <ENTER>.


**************************************************************
*****;

END
bat /p /s goto -top

-%0~1
-$%0$1
-%0%11 beep goto -top1

-on.error-
 if %R > 82 if %R < 90 type !! Floating Point Error !! |goto
-Calc.
 Cls beep type Unexpected batch file error %R in line %L |exit
```

APPENDIX F: EXP2 BATCH CONTROL FILE

```
echo off
CLS
init 1
GRAPHICS
bat /N /p /s
smlt EXP2 -go = -prs = -ls -ns -plm 6 -bw

-top dynex EXP2 -in EXP2.STT -sc -ls -plm 6 -bw
        smlt EXP2 -gm = -ns -plm 6 -bw
        rep EXP2 -outf INTERVAL.OUT -t -bw >NUL
        rep EXP2 -bw >NUL
        infoofb 1
        Call -top1
        Exit
        goto -top%A

-top1   %A = 1
        color \1F
        ram
        cls
        begtype


\1A                          MAIN MENU


\1F          ENSURE YOU HAVE VIEWED THE PROJECT STATUS REPORT

\1F         FOR THIS TIME PERIOD PRIOR TO SELECTING OPTION #2


   \1D 1    \1F VIEW PROJECT STATUS REPORT

   \1D 2    \1F PROCEED TO SIMULATE NEXT TIME PERIOD

Choose an option:\1C DO NOT HIT <ENTER> AFTER SELECTION!!)  ;
end

-1stkey1 inkey %0 | if %0 # = 1 type %0;
        if %0 = key01b return
        goto -%0~1
-2ndkey1 inkey %1 | if %1 # = 1 type %1;
        if %1 = key01b return
        if %1 = key020 goto -$%0$1
        if %1 = key00d goto -$%0$1
```

```
        if %1 = key008 goto -top1
        if %1 = key14b goto -top1
        goto -%0%11

-1~1  **** VIEW PROJECT STATUS REPORT ********************
        rep EXP2 EXP2 -outf EXP2.OUT -t -sc -ls -plm 6 -bw
        INKEY %0
        bat /p /s goto -top1

-2~1  **** PROCEED WITH NEXT SIMULATION *******************
       BAT CLS
       BAT COLOR \1F
       BAT BEGTYPE


*****************************************************************

     1.  DETERMINE YOUR ESTIMATE OF TOTAL PROJECT COST (IN

         MAN DAYS) AND WRITE IT ON THE DOCUMENTATION SHEET.


     2.  DETERMINE YOUR DESIRED STAFFING LEVEL AND WRITE IT

         ON THE DOCUMENTATION SHEET.


     3.  PRESS <ENTER>


*****************************************************************;

END
bat /p /s goto -top

-%0~1
-$%0$1
-%0%11 beep goto -top1

-on.error-
 if %R > 82 if %R < 90 type !! Floating Point Error !! |goto
-Calc.
 Cls beep type Unexpected batch file error %R in line %L |exit
```

APPENDIX G: EXPERIMENT DOCUMENTATION AND INSTRUCTION SET

YOUR NAME: _____
SMC NO: _____

INTRODUCTION

The exercise you are about to undertake is similar in many ways to the flight simulators that pilots use to mimic flying an aircraft from takeoff at point A to landing at point B. Instead of the flight of an aircraft, though, this simulator mimics the life of a real software project from the start of the design phase until the end of testing. In this simulation, you will be more than an observer. In fact, you will play an important role on the project: that of the project manager.

Specifically, your role will be to track the project's progress using a number of status reports that will be produced for you at two-month intervals (40 working days) during the project. As the project manager, you must then update the project's total cost estimate as well as determine the staff size based on the knowledge you gain from these reports. You can hire additional staff or decrease the staffing level as you deem necessary to complete the project.

PROJECT

The project that you will manage happens to have been a real project conducted in a real organization. The particular organization is on the leading edge in software engineering technology. For the project, you will be given a project *profile* containing the following initial information:

Estimated Project Size(in Number of Tasks*)
Estimated Duration(in Number of Work Days)
Estimated Project Cost(in Number of Man Days)
Size of Initial Core Team**(in Number of People)

* A task is a software module that is approximately 50 lines of code in size.

** The Core Team is the group of software professionals that developed the project's requirement specifications. (Remember, you are taking over at the beginning of the Design Phase).

YOUR TASK

Your task is to use the bi-monthly status reports to update the project's total cost estimate (in man days) and to determine a desired staffing level for the remainder of the project. Your objective in setting the staffing level should be to complete the project on schedule.

Note, however, that finishing ahead of schedule will not gain you anything. In fact, it may hurt you, since finishing ahead of schedule will probably mean hiring more staff than needed, thus incurring a higher cost than required.

SOME IMPORTANT THINGS TO CONSIDER IN MAKING YOUR ESTIMATES:

1. This simulation mimics reality very closely. As real managers often do, you will have to use your judgement in coming up with your estimates.

2. As you ponder whether or not you should update the project's cost (in man days), you will be relying on the status report information. This will provide you, for example, with:

(a) Updated Estimate of Total Project Size (in Tasks)

(b) % Development (Design and Code) Reported Complete (Percent)

(c) Total Man Days Expended to Date (Man Days)

3. As part of your task, you will specify the desired staffing level for the remainder of the lifecycle. You may find that the actual staff level may be somewhat different. This will be due to things you cannot totally control such as turnover and lengthy hiring delays.

(a) The personnel turnover rate is 20% per year.

(b) The hiring delay for new employees can take up to 6 weeks. Once new people are hired, the training period for a newly hired employee is typically one month long. This is the time needed to train a new employee in the mechanics of the project and bring him/her up to speed. A new employee (i.e. one that is being trained) is only half as productive as an experienced employee.

4. At different points in the project you will be given information on the status of the project. Three key pieces of information for your task are:

(a) The **"Updated Estimate of Total Project Size"** (this can change to reflect the addition of new requirements).

(b) The **"Total Man Days Expended to Date"**. Subtracting the "Total Man Days Expended to Date" from your "Updated Estimate of Total Man Days" yields the "Remaining Effort in Man Days." For example, if your "Updated Estimate of Total Man Days" is 1000 days, and the "Man Days Expended to Date" figure is 300 days, the Remaining Effort is 700 man days.

(c) The **"Updated Estimate of Project Duration (start-end)"**. In order to determine the "Remaining Time", you subtract the "Elapsed Time" from the "Updated Estimate of Project Duration (start-end)." For example, if the "Updated Estimate of Project Duration (start-end)" is 200 days, and the "Elapsed Time" is 80 days, the Remaining Time is 120 days. It is important to note that this is an estimate which may or may not be totally reliable.

This information could help you figure out, on the one hand, the number of tasks remaining, and on the other, your team's productivity (i.e., tasks developed per man day). But, you must remember that in this project (like in real projects), such status information (e.g., percent reported complete) may or may not be totally reliable. Typically, such status reports are not completely reliable in the earlier phases. However, as the project proceeds, visibility typically improves and with it, the reliability of information. The bottom line is: You will have to use your best judgement.

5. As many projects do, the size of your project may change as the project proceeds (e.g., to reflect changes in user requirements). Again, you will have to use your judgement in using such changes to update your cost and staff.

6. Let us say that at some point in the project the "Remaining Effort" is 1000 man days, the "Remaining Time" is 100 days and you have 7 full time equivalent employees working. You are, thus, in a position where you have to use your judgement to do one of the following:

1. Stick with the current schedule. You will need a staff size of 1000/100 = 10 full time employees.

2. Stick with your staff size of 7. This means the schedule has to be pushed back. In this case the model will make the appropriate adjustment to the schedule for you. (For example, extend it to 1000/7 = 143 man days).

3. Do a bit of both. For example, increase the staff size to 8, which will also mean that the schedule will be extended appropriately by the model to 1000/8 = 125 days.

HOW TO PLAY THE GAME

1. **TRIAL RUN**

(a) Do not start the network. From the C> prompt, change the directory to IS4300.

(b) Type **TEST** to begin the trial run.

(c) The system will show you some introductory screens and instructions.

(d) The simulation will run through the first simulation time period and show you the "MAIN MENU".

(e) **DO NOT HIT ENTER AFTER MENU SELECTIONS**. Press **1** to view the status report. Please be sure you understand it before continuing.

(f) Press **<ENTER>** to return to the Main Menu. At the Main Menu, press **2** to prepare for another simulation.

(g) The screen will prompt you to enter an estimate of total project cost and staff requirements before performing the next simulation. Perform steps (d) through (f) for as many intervals as necessary (by pressing **2** at the Main Menu), until you are comfortable with the system. Run the project for a minimum of 2 intervals.

(h) After you are finished with the Trial Run, hit **<ESC>** when you are at the "MAIN MENU" screen to exit. This is the only time you should hit <ESC>.

(i) Remain in IS4300 directory. Proceed to the experiment (Para 2).

2. **EXPERIMENT**

(a) Type **EXP1** to run the project.

(b) Follow instructions (c) through (f); ensure you write your estimates on the documentation sheet and enter them in the computer before proceeding with each interval simulation.

(c) Your project is considered complete when "% Reported Complete"=100 for both development (e.g., Design and Coding) and testing.

APPENDIX H: EXPERIMENT DECISION RECORD SHEET

Management's Initial Project Estimates

Initial Estimate of Project Size: 396 Tasks
Initial Estimate of Project Cost: 1,111 Man Days
Initial Estimate of Project Duration: 320 Days
Size of Initial Core Team: 5 People

A project is considered complete when "% Reported Complete" = 100 for both development work (i.e., Design and Coding) and testing.

Please enter your project cost estimates and staffing decisions below:

	PROJECT COST	STAFFING(PEOPLE)
Time elapsed - 40 days:	_____	_____
Time elapsed - 80 days:	_____	_____
Time elapsed - 120 days:	_____	_____
Time elapsed - 160 days:	_____	_____
Time elapsed - 200 days:	_____	_____
Time elapsed - 240 days:	_____	_____
Time elapsed - 280 days:	_____	_____
Time elapsed - 320 days:	_____	_____
Time elapsed - 360 days:	_____	_____
Time elapsed - 400 days:	_____	_____
Time elapsed - 440 days:	_____	_____
Time elapsed - 480 days:	_____	_____
Time elapsed - 520 days:	_____	_____

*** **WHEN YOU ARE DONE, CALL FOR A LAB ATTENDANT** ***

APPENDIX I: SAMPLE POPULATION RANDOMIZING WORKSHEET

IS 4300				SEGMENT 1	
A	B	C	D	E	F
BOWMAN	90	YOUNGBLOOD	36	LOCKHART	A
BROADWATER	58	ROSS	52	STEIN	B
BRYANT	55	MAIN	06	WRIGHT	A
CHELOUCHE	89	CULPEPPER	44	HALE	B
CHICHESTER	53	FEY	65	MAIN	A
CULPEPPER	12	HALE	05	CHICHESTER	B
FEY	21	KROTOW	55	IVEY	A
FOOTE	60	WRIGHT	03	WHITE	B
HALE	25	LOCKHART	01	SALTERS	A
IVEY	84	STEELE	57	MCDONALD	B
KROTOW	29	PASADILLA	82	YOUNGBLOOD	A
LLANETA(ROGERS)	95	SALTERS	24	FOOTE	B
LOCKHART	33	WHITE	23	CULPEPPER	A
MAIN	10	SOONG	95	ROGERS	B
MCDONALD	67	CHICHESTER	20	ROSS	A
PASADILLA	38	BRYANT	69	KROTOW	B
ROSS	08	BROADWATER	75	STEELE	A
SALTERS	42	FOOTE	37	BOWMAN	B
SOONG	49	MCDONALD	26	FEY	A
STEIN	80	STEIN	02	BRYANT	B
WHITE	43	IVEY	22	CHELOUCHE	A
WRIGHT	32	CHELOUCHE	75	BROADWATER	B
YOUNGBLOOD	00	BOWMAN	65	PASADILLA	A
STEELE	34	LLANETA(ROGERS)	49	SOONG	B

IS 4300				SEGMENT 2	
A	B	C	D	E	F
BELL	06	GORMAN	94	POSEY	A
BITTNER	42	OWEN	87	LANE	B
BOYD	62	BELL	95	LACO	A
BRANLEY	47	SHANNON	66	RANDALL	B
CLARK	71	LACO	06	TOY	A
DEFORD	59	HODGKINS	30	RUST	B
FOSTER,S	93	SABENE	40	HODGKINS	A
FOSTER,T	54	RANDALL	10	POWERS	B
GORMAN	01	RUST	26	SABENE	A
HODGKINS	11	LANE	02	CLARK	B
LACO	08	RHOADS	57	FOSTER,T	A
LANE	26	BITTNER	65	RHOADS	B
METCALF	67	BRANLEY	87	METCALF	A
MONK	94	POSEY	00	DEFORD	B
NOLAN	77	PENCE	91	BITTNER	A
OWEN	02	FOSTER,T	54	SHANNON	B
PENCE	49	FOSTER,S	95	NOLAN	A
POSEY	48	SMITH	98	MONK	B
POWERS	82	DEFORD	64	BRANLEY	A
RANDALL	15	TOY	13	OWEN	B
RHOADS	27	BOYD	94	PENCE	A
RUST	19	METCALF	60	BOYD	B
SABENE	12	CLARK	43	GORMAN	A
SHANNON	07	NOLAN	70	FOSTER,S	B
SMITH	07	POWERS	31	BELL	A
TOY	60	MONK	71	SMITH	B

APPENDIX J: SAS DATA AND CONTROL FILES FOR MANOVA

FINAL SCHEDULE AND COST

```
OPTIONS LINESIZE=80;
DATA;
INPUT NAME $  GROUP $  SCHED  COST;
INICOST=1111.00;
INISCHED=320;
DIFFSKED=(SCHED-INISCHED)/INISCHED;
DIFFCOST=(COST-INICOST)/INICOST;
COSTSKED=(DIFFCOST+DIFFSKED)/2;
CARDS;
BELL A 297 1523.78
BITTNER A 302 1676.24
BRANLEY A 282 1909.99
CHELOUCHE A 372 1556.33
CULPEPPER A 317 1652.09
FEY A 283 1594.33
FOSTERT A 398 1531.88
HODGKINS A 292 1615.32
IVEY A 305 1532.61
LACO A 311 1480.42
LOCKHART A 364 1604.34
MAIN A 280 1884.17
METCALF A 402 1529.94
PASADILLA A 277 1604.49
PENCE A 347 1829.35
POSEY A 330 1516.01
SABENE A 417 1571.73
SALTERS A 240 1719.99
STEELE A 355 1783.24
TOY A 322 1680.84
WRIGHT A 380 1680.84
YOUNG A 269 1540.98
BOWMAN B 371 1579.01
BOYD B 274 1613.38
BROADWATER B 321 1686.92
BRYANT B 339 1595.71
CHICHESTER B 213 1657.98
CLARK B 253 1668
DEFORD B 361 1659.11
FOOTE B 245 1625.93
FOSTERS B 328 1553.51
HALE B 282 1590.12
KROTOW B 260 1691.94
LANE B 402 1552.16
```

```
MCDONALD B 192 1894.69
MONK B 295 1643.82
OWEN B 262 1689.53
POWERS B 266 1529.39
RANDALL B 343 1617.03
RHOADS B 266 1976.98
ROGERS B 273 1605.92
RUST B 297 1769.05
SHANNON B 330 1676.37
SMITH B 312 1752.03
SOONG B 294 1622.87
STEIN B 208 1648.15
WHITE B 269 1656.34
;
PROC SORT; BY GROUP;
PROC MEANS;
    VAR DIFFCOST DIFFSKED COSTSKED;
    BY GROUP;
    TITLE 'STATISTICS OF GROUPS A AND B';
PROC GLM;
    CLASS GROUP;
    MODEL DIFFCOST DIFFSKED=GROUP;
    MANOVA H=GROUP / PRINTE PRINTH;
    TITLE 'MULTIVARIATE ANOVA OF GROUPS A AND B';
PROC ANOVA;
    CLASSES GROUP;
    MODEL COSTSKED=GROUP;
    TITLE 'COST + SCHED ANOVA FOR GROUPS A AND B';
```

NOTE: GROUP GRADUAL = GROUP A; GROUP ABRUPT = GROUP B

APPENDIX K: SAS DATA AND CONTROL FILES FOR REPEATED MEASURES

STAFF DECISION REPEATED MEASURES

```
OPTIONS LINESIZE=80;DATA;INPUT NAME $ GROUP $ T1 T2 T3 T4 T5
T6;
CARDS;
BELL A 5 5.3 5.5 5.5 5.6 6.2
BITTNER A 5 6 6 6 7 7
BRANLEY A 5.96 6.5 7.7 7.7 10.2 10.2
CHELOUCHE A 4 4 3 3 4
CULPEPPER A 5 5 7 7 7 4
FEY A 5 5 4.8 5.6 8 5
TFOSTER A 5 5 5 5 5 3
HODGKINS A 5.5 5.5 6 6.5 6.5 6.8
IVEY A 6 6 6 6 5 4
LACO A 5.5 5.5 4.9 4.9 4.8 4.8
LOCKHART A 4.5 4 3.5 3.5 5.5 6
MAIN A 7 7 7.5 8.5 8.5 8.5
METCALF A 6 6 5.5 2.6 2 2
PASADILLA A 5 6 6 7 8 8
PENCE A 6 6 6 5 5 5
POSEY A 6 6 6 5 4 4
SABENE A 5 5 1 1 1 5
SALTERS A 5.5 10.5 10.5 10.5 6 5
STEELE A 6 6 6 4.5 4.5 4.5
TOY A 5 5.5 5 5 5 6
WRIGHT A 5 5 6 5 5 6
YOUNG A 6 6 6.5 6.5 7 7
BOWMAN B 5 4 6 3 3 5
BOYD B 5 6 7 8 8 6
BROADWATER B 5 5 6 6 6 6
BRYANT B 4.5 4 6 6 6 5
CHICHESTER B 9 10 10 10 10 .
CLARK B 5.5 7 10 8 8.5 8.5
DEFORD B 5 4 4 5 5 5
FOOTE B 6 7 8 9 10 10
SFOSTER B 5 5 5 5 5 5
HALE B 5.5 5.5 6.5 6.5 7 7
KROTOW B 6 6 11 8 8 8
LANE B 6 5 5 4 2 2
MCDONALD B 7 12 20 20 . .
MONK B 5 5 7.5 7.5 7.5 5
OWEN B 5 6 9 9 9 7
POWERS 5 5 5.3 3.5 3 4
RANDALL B 5 5 5 5 5 6
```

```
RHOADS B 6.5 6.5 12.1 12.1 8 9
ROGERS B 6 6 7 7 7 7
RUST B 6 6 7 7 7 7
SHANNON B 5 5 6 6 5.5 5
SMITH B 3.5 3.5 3.5 8.9 8.9 8.9
SOONG B 5 5 6 6 7 8
STEIN B 10 10 10 10 10
WHITE B 7 7 7 7 7 7
;
PROC SORT; BY GROUP;
PROC GLM;
    CLASS GROUP;
    MODEL T1-T6=GROUP/NOUNI;
    REPEATED TIME / SHORT SUMMARY;
    TITLE 'STAFFING LEVEL DECISIONTS';
    TITLE3 'REPEATED MEASURES FOR GROUP A VERSUS GROUP B';
```

NOTE: GROUP GRADUAL = GROUP A, GROUP ABRUPT = GROUP B

APPENDIX L: SAS DATA AND CONTROL FILES FOR REPEATED MEASURES

PROJECT COST ESTIMATE DECISION REPEATED MEASURES

```
OPTIONS LINESIZE=80;DATA;INPUT NAME $ GROUP $ T1 T2 T3 T4 T5
T6;
CARDS;
BELL A
BITTNER A 5 6 6 6 7 7
BRANLEY A 5.96 6.5 7.7 7.7 10.2 10.2
CHELOUCHE A 4 4 3 3 4
CULPEPPER A 5 5 7 7 7 4
FEY A 5 5 4.8 5.6 8 5
TFOSTER A 5 5 5 5 5 3
HODGKINS A 5.5 5.5 6 6.5 6.5 6.8
IVEY A 6 6 6 6 5 4
LACO A 5.5 5.5 4.9 4.9 4.8 4.8
LOCKHART A 4.5 4 3.5 3.5 5.5 6
MAIN A 7 7 7.5 8.5 8.5 8.5
METCALF A 6 6 5.5 2.6 2 2
PASADILLA A 5 6 6 7 8 8
PENCE A 6 6 6 5 5 5
POSEY A 6 6 6 5 4 4
SABENE A 5 5 1 1 1 5
SALTERS A 5.5 10.5 10.5 10.5 6 5
STEELE A 6 6 6 4.5 4.5 4.5
TOY A 5 5.5 5 5 5 6
WRIGHT A 5 5 6 5 5 6
YOUNG A 6 6 6.5 6.5 7 7
BOWMAN B 5 4 6 3 3 5
BOYD B 5 6 7 8 8 6
BROADWATER B 5 5 6 6 6 6
BRYANT B 4.5 4 6 6 6 5
CHICHESTER B 9 10 10 10 10 .
CLARK B 5.5 7 10 8 8.5 8.5
DEFORD B 5 4 4 5 5 5
FOOTE B 6 7 8 9 10 10
SFOSTER B 5 5 5 5 5 5
HALE B 5.5 5.5 6.5 6.5 7 7
KROTOW B 6 6 11 8 8 8
LANE B 6 5 5 4 2 2
MCDONALD B 7 12 20 20 . .
MONK B 5 5 7.5 7.5 7.5 5
OWEN B 5 6 9 9 9 7
POWERS 5 5 5.3 3.5 3 4
RANDALL B 5 5 5 5 5 6
```

```
RHOADS B 6.5 6.5 12.1 12.1 8 9
ROGERS B 6 6 7 7 7 7
RUST B 6 6 7 7 7 7
SHANNON B 5 5 6 6 5.5 5
SMITH B 3.5 3.5 3.5 8.9 8.9 8.9
SOONG B 5 5 6 6 7 8
STEIN B 10 10 10 10 10
WHITE B 7 7 7 7 7 7
;
PROC SORT; BY GROUP;
PROC GLM;
    CLASS GROUP;
    MODEL T1-T6=GROUP/NOUNI;
    REPEATED TIME / SHORT SUMMARY;
    TITLE 'STAFFING LEVEL DECISIONTS';
    TITLE3 'REPEATED MEASURES FOR GROUP A VERSUS GROUP B';
```

NOTE: GROUP GRADUAL = GROUP A; GROUP ABRUPT = GROUP B

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